

MAHSA Training
QGIS and its Application in Archaeology
Level I / Beginner Training



Tutorial 2 - Georeferencing Historic Maps

This tutorial was developed by Azadeh Vafadari, MAHSA Project Training Coordinator, as part of the MAHSA training initiative.



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Date:
Version 3.0 - March 2026

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Introduction

This tutorial builds on the foundational skills introduced in Tutorial 1 by focusing on the acquisition and spatial alignment of historic maps within QGIS. Georeferencing is a key technique in GIS and archaeological research, allowing historical cartographic materials to be accurately positioned within a modern coordinate system.

You will begin by exploring how to locate and download digitised historic maps from a range of online repositories. The tutorial then introduces the georeferencing process in QGIS, guiding you through both basic and more advanced methods. You will learn how to use corner coordinates for initial alignment, and how to improve accuracy by selecting Ground Control Points (GCPs) based on identifiable landscape features.

By the end of this tutorial, you will understand how to transform scanned maps into spatially accurate datasets that can be integrated with modern geospatial data, supporting analysis of landscape change and archaeological features over time.

Key Takeaways

By completing this tutorial, you should be able to:

- Identify and access reliable sources of digitised historic maps

- Download and organise raster map data for use in QGIS
- Understand the concept and importance of georeferencing in GIS
- Set up and manage a QGIS project for georeferencing workflows
- Use the Georeferencer tool to align raster images with real-world coordinates
- Apply georeferencing using corner coordinates for initial map placement
- Improve spatial accuracy by selecting and managing Ground Control Points (GCPs)
- Interpret residual error values to assess georeferencing accuracy
- Use tools such as transparency and Map Swipe to compare datasets
- Save and reload georeferencing work, including GCP files
- Produce accurately georeferenced raster outputs for further analysis

Finding and Downloading Historic Maps

A Survey of India map has been provided for you for this tutorial, so you do not need to find and download a map. However, it is very important to know where maps can be found and downloaded from. Several websites have maps available to download that are suitable for georeferencing.

One of the main online repositories of map collections is the University of Texas Libraries website, which hosts the Perry-Castaneda Library map collection - <https://maps.lib.utexas.edu/>

This map collection has thousands of scanned paper maps that are available for download. The maps are organised geographically by region and country.

As an example, to download a map from India:

- Open the University of Texas Libraries website (link above).
- Navigate to the PCL Map Collection link.



UT Libraries' Map Collection

Ask a Map Question >

Collections Portal GeoData Portal

PCL Map Collection Map Guide

<https://maps.lib.utexas.edu/maps/index.html>

- Scroll down and select the Asia link.

PCL Maps

Africa	Americas	Asia
Australia/Pacific	Russia/Republics	Europe
Historical	Middle East	Polar/Oceans
Texas	Thematic	Topographic
U.S.	World	

- Search for your country of interest, for example India (highlighted in red in the below image).

- maps -----
- Eurasia (Political) 2006 (4.5MB)
 - **Gaza and West Bank Maps**
 - **Georgia Maps**
 - **Hong Kong Maps**
 - **India Maps**
 - **Indian Ocean Maps**
 - Indochina (Shaded Relief) 1985 (342K)
 - **Indochina and Thailand, Series L506** (Topographic Maps) 1:250,000, U.S. Army Map Service, 1954-
 - **Indochina Atlas** 1970
 - Indochina Ethnolinguistic Groups From Indochina Atlas, 1970 (654K)
 - **Indonesia Maps**

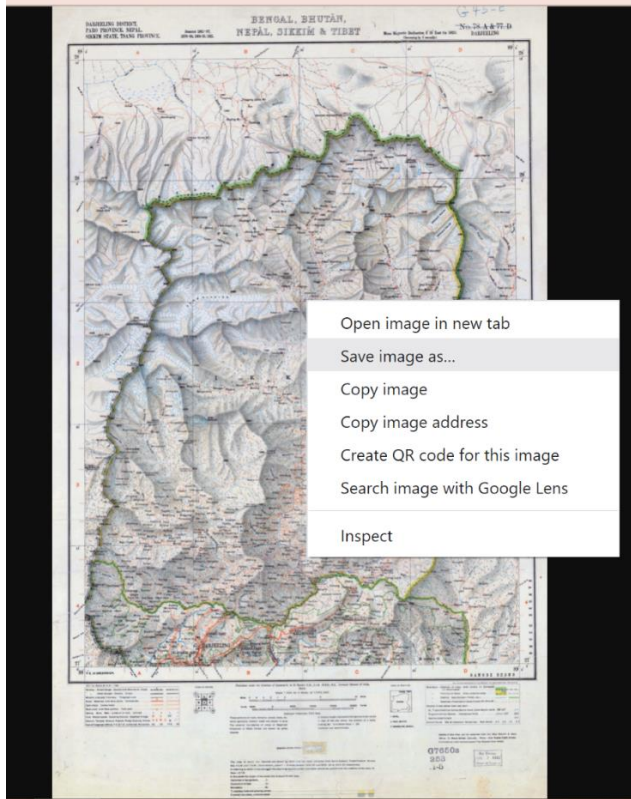
- Choose the map series that you would like. Note that maps useful for archaeologists are usually grouped under “Historical Maps”. For example, choose the 1:253,440 India Topographic Maps (Historical) (as highlighted below).

Historical Maps

- 1:1,000,000 - India and Adjacent Countries Topographic Maps Survey of India
This series covers most of India
 - 1:253,440 - India Topographic Maps Series 3919 & 4218, Great Britain War Office
This series covers part of Northern India
 - Bhuj-Anjar Area, Gujarat (Topographic Map) original scale 1:250,000. Portion of Sheet NF 42-3, Series U502, U.S. Army
 - Bombay 1909 from The Gazetteer of Bombay City and Island. Volume 1. Bombay, India 1909 (386K)
 - Bombay 1954 (City Plan) original scale 1:50,000 U.S. Army Map Service 1954 (233K)
 - Bombay - North 1954 (Topographic Map) original scale 1:250,000. Portion of Kalyan, Sheet NE 43-1, Series U502, U.S.
 - Bombay - South 1954 (Topographic Map) original scale 1:250,000. Portion of Bombay, Sheet NE 43-5, Series U502, U.S.
 - Calcutta 1945 (City Plan) from The Calcutta Key: Welcome United States Army. United States Army Forces in India-Bur
- Sometimes map series have index maps that will help you find specific map sheets.

PCL Map Collection > India Topographic Maps

- Otherwise you can just search and browse until you find a useful map to click on.
- Select a map sheet that you would like to use. It will then load up. Right click on it, select ‘Save Image As’ and save it in your GIS folder.



Maps can also be downloaded from many other sources, such as The National Library of Australia Trove website: <https://trove.nla.gov.au/>

Another site you can explore is: <https://www.oldmapsonline.org>

For the Survey of India maps we have compiled a list of the repositories in the UK in this document: [MAHSA Guide to Survey of India Maps](#). Examples for online databases of South Asia maps from this list are Pahar (<http://pahar.in/>) and Zenodo (<https://zenodo.org/record/3595575#.YV7NOrhKg2w>).

Corona satellite imagery can also be very useful for archaeologists. Some georeferenced Corona imagery is available to view and download on the [Corona Atlas & Referencing System website](#): However, the imagery available is limited for South Asia. More information about Corona imagery and its use in the detection and monitoring of archaeological sites will be part of our future training and workshops.

Georeferencing in QGIS

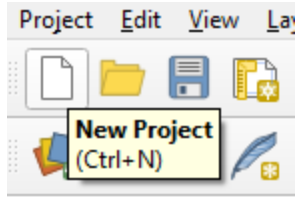
After obtaining a digitised historic map, we will now learn how to georeference it so that the features on the map can be related to their true locations on the Earth.

For this tutorial you will use the map titled 53_C_3_1915.tif, in the folder *Map sheet to georeference*.

1. Starting a new project

First, we need to start a new project and set the CRS.

- To begin, open QGIS then select *Project -> New Project* or click the new project button.



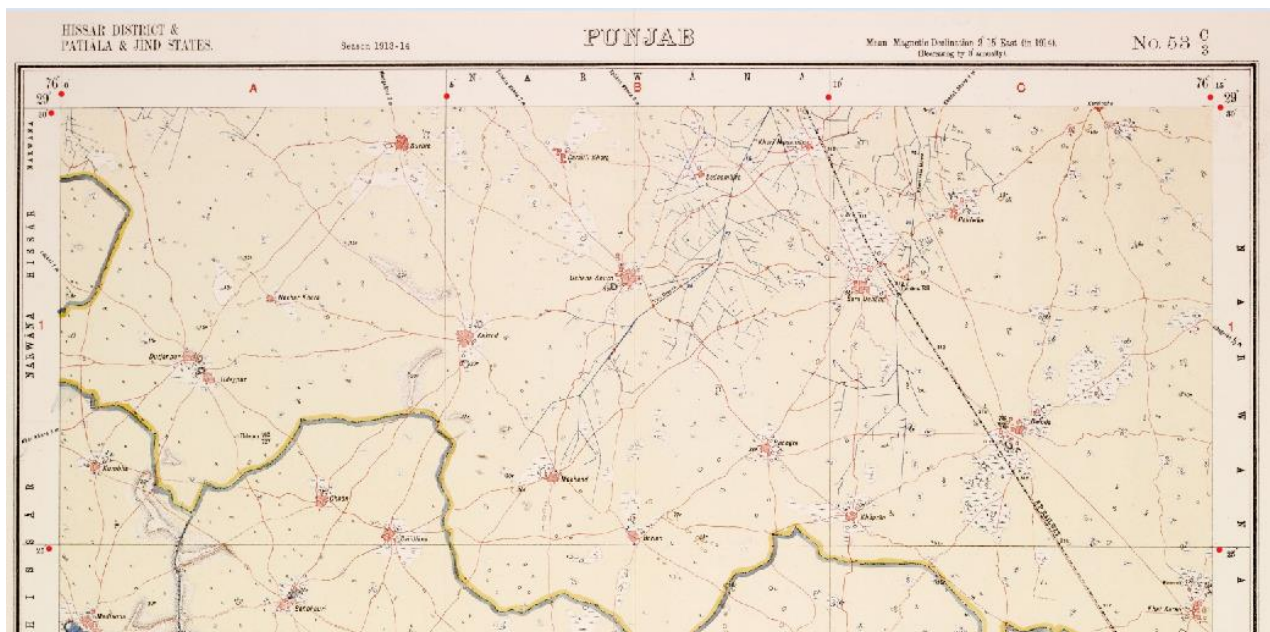
- Save the new project with a relevant name, for example 'georeferencing_project.gqz'.

When georeferencing, it is useful to use a CRS that is similar to the one that the paper map was drawn in. We therefore need to inspect that map to see if we can find out this information

- First, we will open the map in Windows Photo Viewer. To do this, double click on the map file.
- Inspect the map to see if you can find any details on its CRS. If there are any details about the CRS it is often found as part of the key and may be labelled *Projection*.

However, in the map that we are georeferencing, there is no specific reference to the CRS that it was drawn in, so we have to look for other details that may help us.

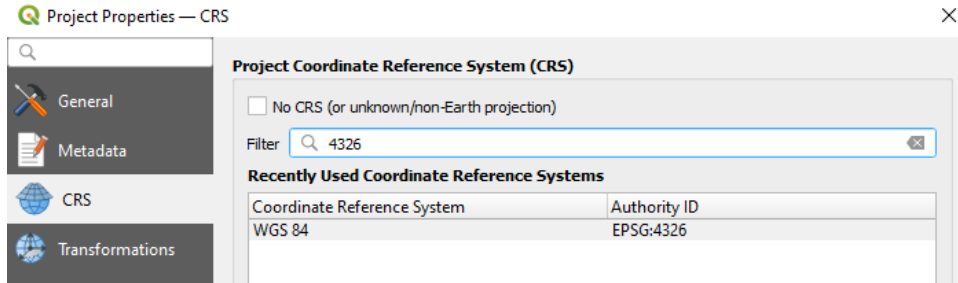
You will see that the map has a grid drawn over the top of it. If you look around the edge of the map, you will be able to see that each line of the grid has a specific number related to it (red dots in the figure below). These are coordinates in degrees and minutes.



Due to the age and location of the map, it is likely that it was drawn in the CRS Everest 1830. We will not set our CRS to Everest 1830, but instead we will make sure that it is set to WGS 1984. This is because this is a standard CRS for use in cartography and is also measured in coordinates in degrees and minutes.

As a different reference ellipsoid has been used to create WGS 84, the locations of the coordinates will be slightly different to Everest 1830, however they will roughly be in the same location.

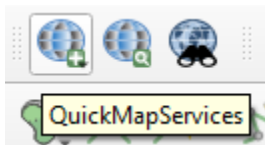
- Make sure the project coordinate system is set to EPSG 4326 – WGS1984. Select *Project* -> *Properties* -> *CRS*. Enter 4326 in the filter box, select *WGS1984* then click apply and ok.



- Save the project.

2. Load a basemap

- Click on the *QuickMapServices* icon on the taskbar.

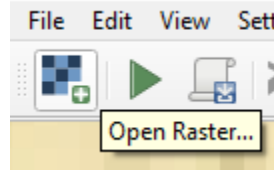


- Select a satellite basemap, this could be 'Google Satellite', 'Bing satellite', 'ESRI satellite' etc.
- Once selected, your basemap will appear in the Layers Panel.

3. Load the map into the georeferencer.

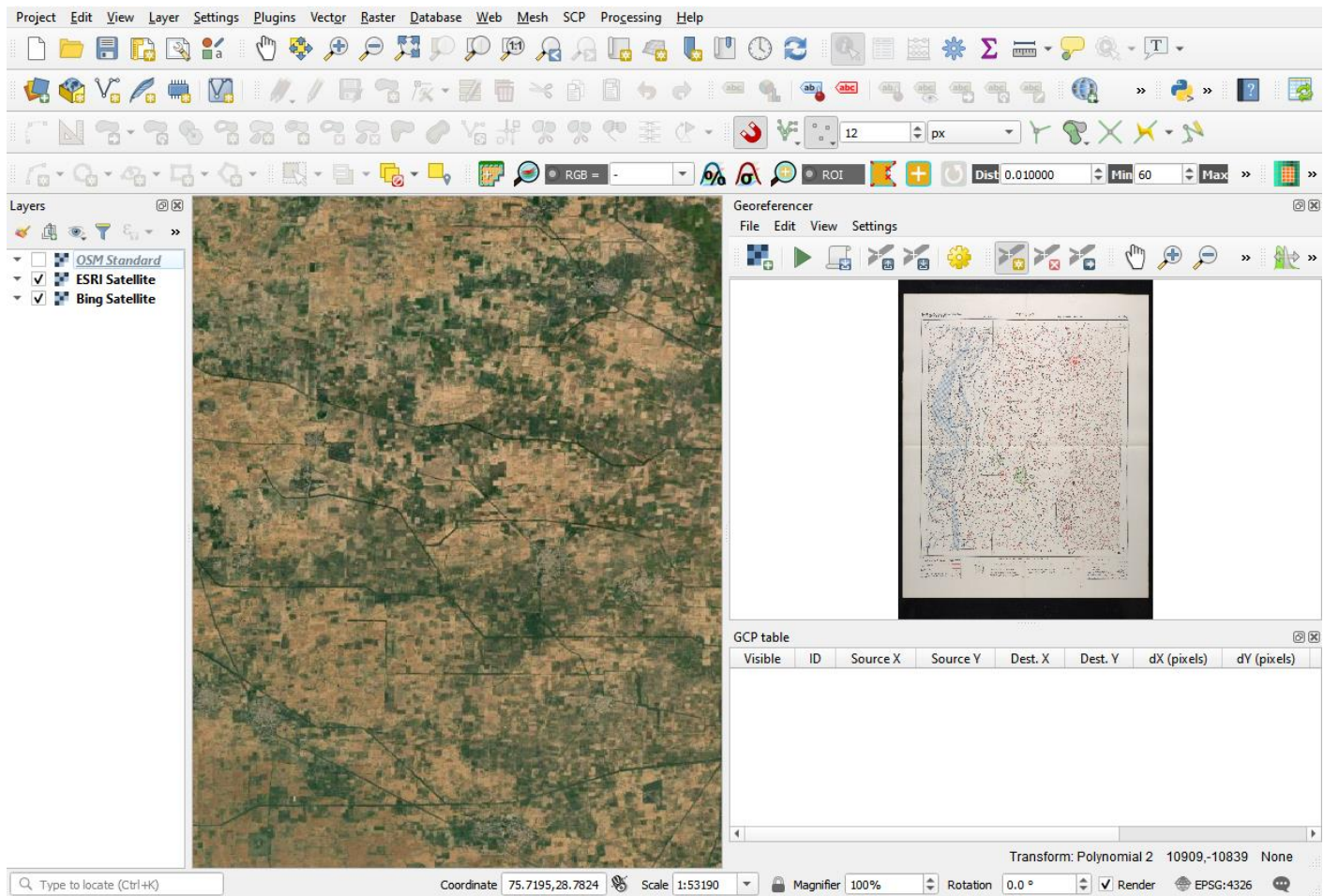
We now need to load the georeferencer plugin and open our digitized raster image into it.

- On the taskbar, select *Layer -> Georeferencer*. Your cursor should become a small cross and the Georeferencer Panel will open. To learn more about what all of the buttons in the Georeferencer Panel do, visit this website - https://docs.qgis.org/3.34/en/docs/user_manual/working_with_raster/georeferencer.html
- In the Georeferencer Panel, click on the *Open Raster* button and navigate to the raster image that you are going to georeference, and click Open.



The georeferencer window will open as a floating window. It can be easier to have this docked alongside the basemap (please note this is sometimes not possible when using QGIS on Mac OS).

- To do this, in the georeferencer window select *Settings -> Configure Georeferencer* and then tick the box next to *Show Georeferencer window docked*. The window will dock underneath your basemap.
- To view the two windows side by side, click and hold in an empty area of the georeferencer menu bar and drag it to the right-hand side of the screen until a blue highlighted area appears.
- Let go of the click and the georeferencer window will move.



Georeferencing using corner coordinates

We will first georeference the map using the corner coordinates. This will position the map in generally the correct location, and will be useful for finding GCPs later in the tutorial.

- In the Georeferencing window, select the transformation icon, or select *Settings -> Transformation Settings* and enter the following settings:

Transformation Settings

Transformation Parameters

Transformation type: Polynomial 1

Target CRS: Project CRS: EPSG:4326 - WGS 84

Output Settings

Output file: [] ...

Resampling method: Nearest Neighbour

Compression: None

Create world file only (linear transforms)

Use 0 for transparency when needed

Set target resolution

Horizontal: 0.00000

Vertical: 0.00000

Reports

Generate PDF map: [] ...

Generate PDF report: [] ...



Save GCP points

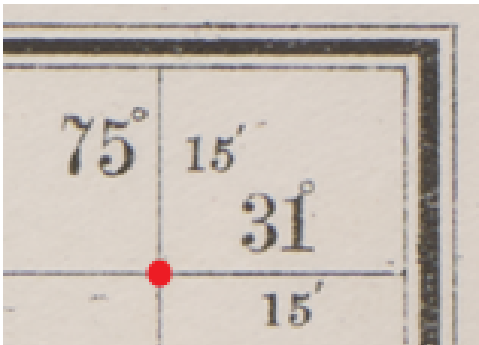
Load in project when done

OK Cancel Help

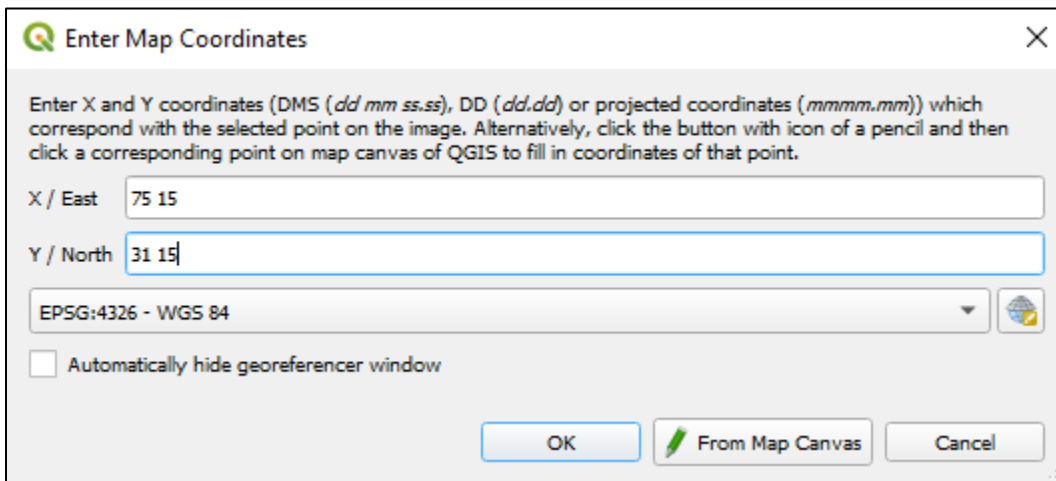
- Input a location and name for the output georeferenced raster by clicking the three dots [...] next to the *Output raster* field. You may want to first create a new folder that can be used to store all of your outputs from this tutorial. Save the file name as '53_C_3_1915 _corners.tif'. Adding '_corners' at the end is necessary so that we know that this map has been georeferenced by its corner coordinates only.
- Click OK.

We will now create GCPs for the 4 corner coordinates of the map.

- Select the *Add point* tool in the georeferencer  in the new version of QGIS the icon looks like this: 
- Zoom-in on the top right corner of the map and click at the point where the corner latitude/longitude lines meet (indicated by a red point in the below image).



- A new window will open, and you will be prompted to enter the coordinates into it. Do so by entering them in the format *dd mm* (where *dd* is degrees and *mm* is minute).



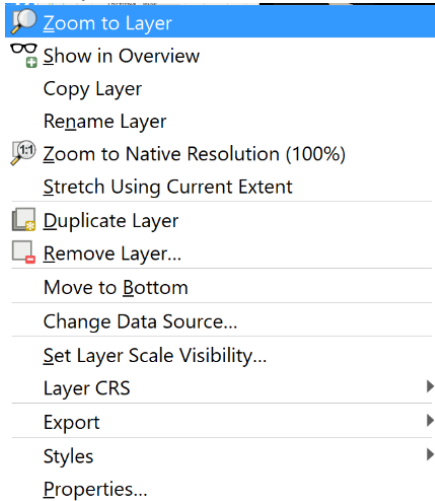
- Click OK, and a new entry will appear in the *Georeferencer table*.
- Repeat this process with all four corners of the map.

When all four corners have been entered, the georeferencer has enough information to roughly fit the map into the CRS using the Polynomial 1 transformation method. To do this:

- Click the 'Start Georeferencing' button.



- The georeferencer will run, and once complete a new tif file will be saved in your chosen location, as well as a *.points* file (this file holds the information about the GCPs that you have selected). The georeferenced raster map will also appear in the Layer Panel in QGIS.
- To view the digitised map on top of the basemap, right click on the georeferenced map layer in the Layers Panel, and select *Zoom to Layer*.



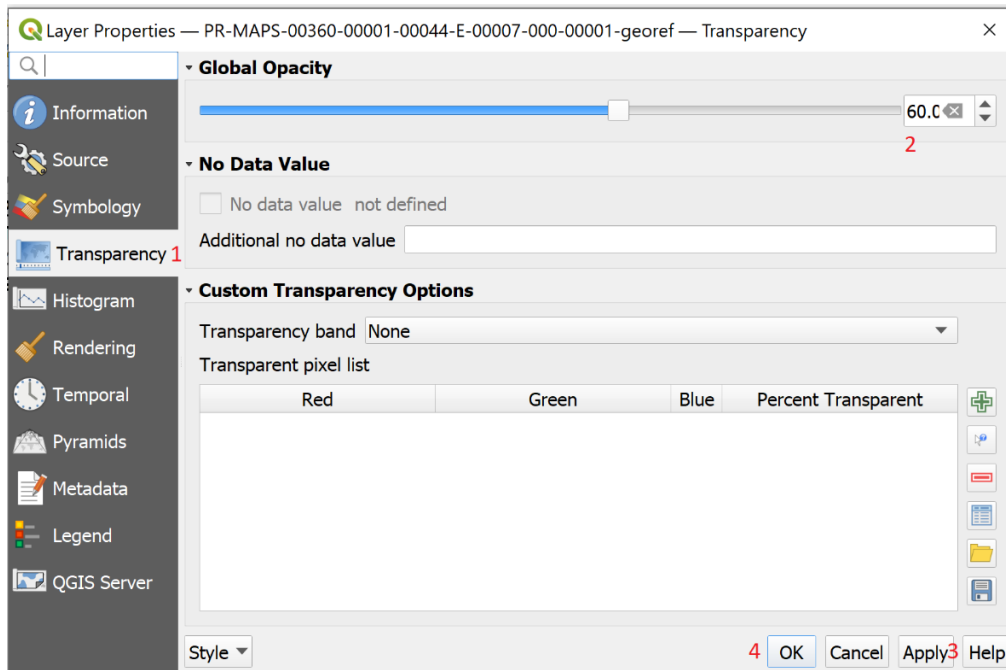
- You can now see your georeferenced map in the correct location on top of the basemap.
- Now save the project (this is important in case you want to reload QGIS to show this layer at some time in the future).

There are a couple of other ways to visualise this map on top of the basemap. These are by either changing the layer transparency or using the MapSwipe Tool. Instructions for both of these follows.

Changing map transparency

If you change the transparency of the georeferenced map layer, the basemap layer will be more visible under the georeferenced map layer, thus making the comparison between both layers easier.

- Right click on the layer, and then click on *Properties > Transparency* (step 1 in the below image).
- Set the *Global Opacity* to 60% (step 2).
- Apply (Step 3) and OK (step 4).



You map view should now look something like this:

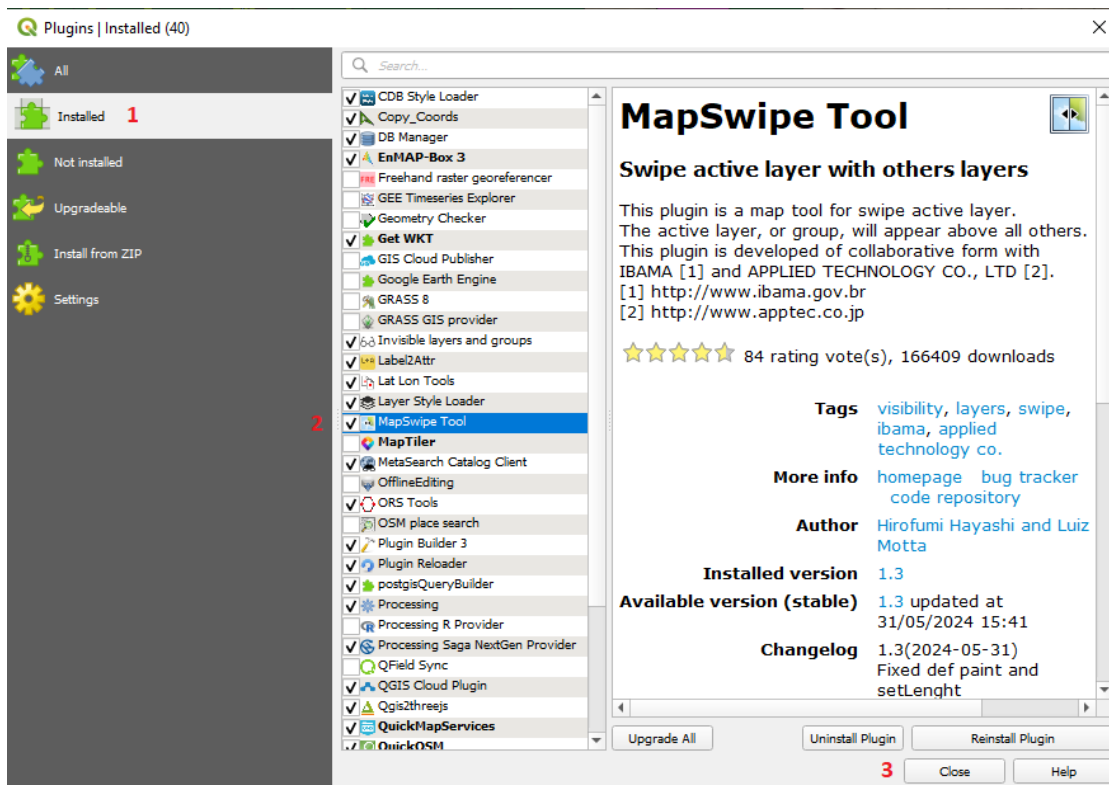


Using the Map Swipe tool

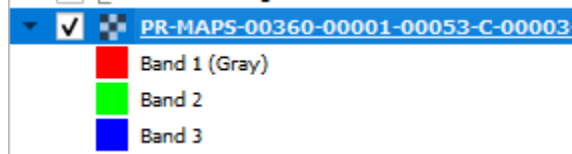
The second way to compare your georeferenced map and the basemap is to use the Map Swipe tool plugin.


Please first check that this plugin is installed:

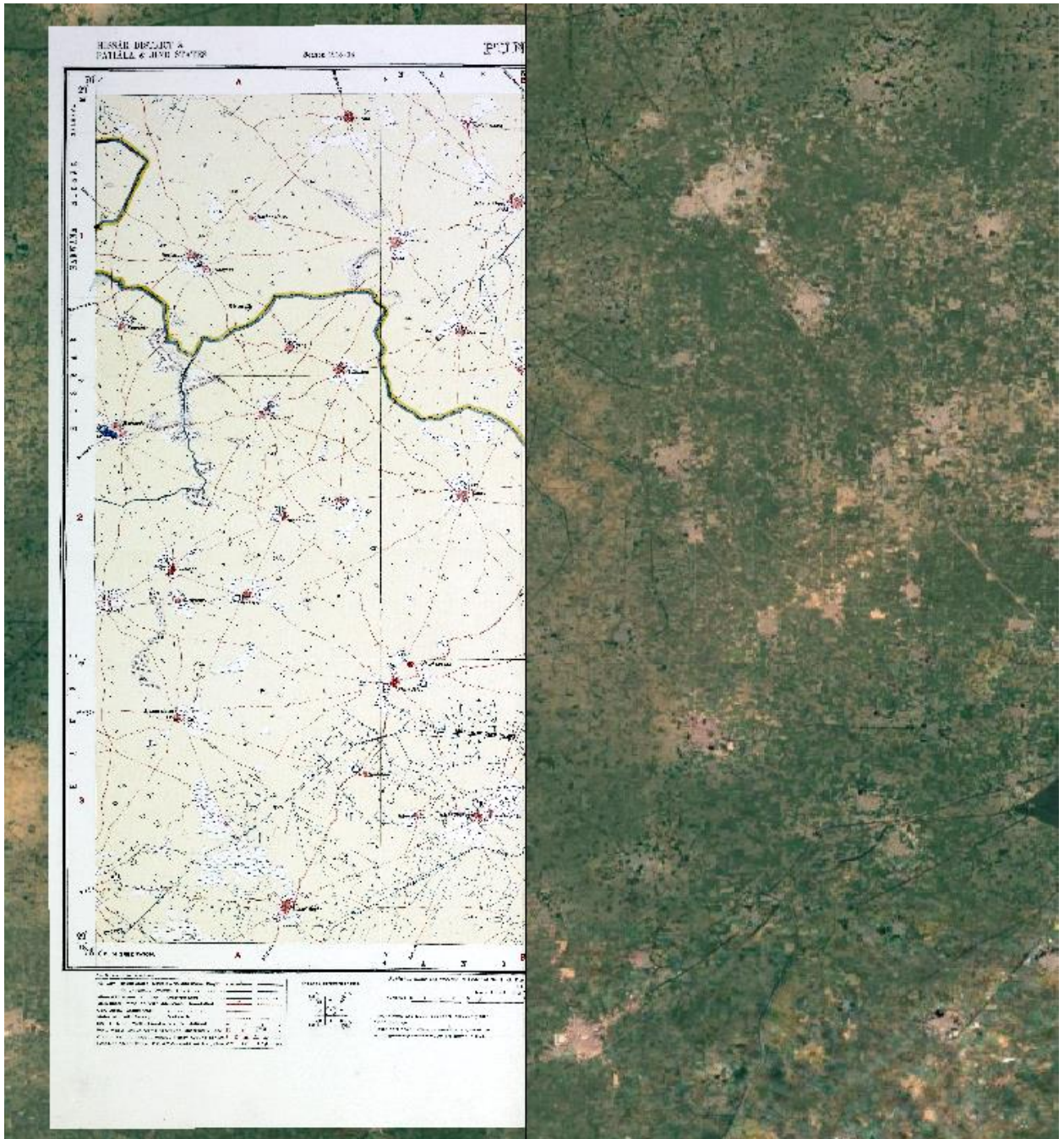
- In QGIS click on *Plugins* and then *Manage and Install Plugins*.
- Click on *Installed* on the left-hand side of the panel (step 1 in the below image) and have a look in the list to see if 'MapSwipe Tool' is listed and that the checkbox next to it is checked (step 2). Then click on *Close* (step 3).
- If you cannot see the MapSwipe tool in your installed plugins list you will have to install it. Instructions on how to install a plugin can be found in the tutorial 1 document.



- In the main QGIS window, left click on your georeference map layer in the Layers panel. It should highlight that layer in blue:



- Then navigate to the MapSwipe Tool icon  and click on it. This will activate the tool and your layer map appear to disappear from the map.
- Now left click and hold on the map window and move your cursor side to side. You will see that your georeferenced map will now swipe on and off across the basemap.



- When you have finished using the tool, click on the MapSwipe Tool icon again to turn it off.

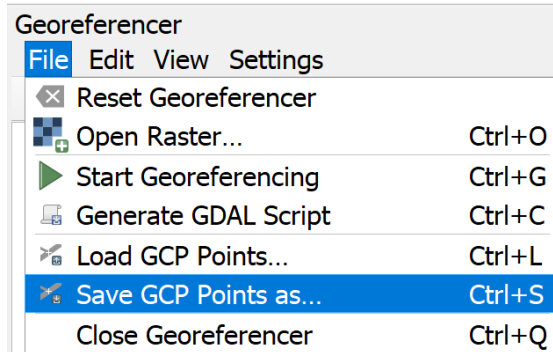
Using either the MapSwipe Tool or by adjusting the map transparency, zoom in to some areas of the map and compare the georeferenced map with the basemap. You will be able to see that the map is georeferenced roughly in the correct location. However, we can make the georeferencing more accurate by selecting GCPs based on features rather than coordinates.

Practice: Follow the steps above and use the georeferencer to georeference 4 corners of the map titled 53_C_3_1915.tif (which is in the folder *Map sheet to georeference*), then compare with the basemap by adjusting the layer transparency and using the MapSwipe Tool.

Reopening a saved project and reloading georeferencer

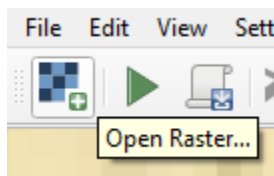
It is important to know how to reopen your project and reload the georeferencer in case you need to exit QGIS when you are halfway through georeferencing a map.

- Before exiting, make sure you have saved your project, and the GCP file.
 - ❖ If you have just finished georeferencing a map, you should have a GCP file saved with the georeferenced map. Check in the folder that you have saved your georeferenced map to see if there is a .gcp file there.
 - ❖ If you are halfway through georeferencing a map, save the GCP file. Click on *File > Save GCP Points as...* in the Georeferencer panel

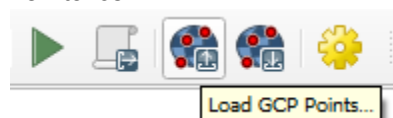


Either select a GCP file that you have already made and save over it, or save a new GCP file with the same name as your map sheet but with an extension of .gcp (for example 53_C_3_1915.gcp)

- You are now safe to exit QGIS and reopen it to continue at the point where you are.
- Open QGIS.
- Click on *Project>Open* and select the saved project file. This will open your layers focused on the geographic location where you saved the project, however it will not reload the georeferencer.
- Go to *Layer>Georeferencer*
- When the georeferencer window opens click on the *Open Raster* button



- Select the **un-georeferenced** tif file for your map.
 - ❖ Please note it is very important that you **open the raw, un-georeferenced file**, the same one that you initially opened here in the previous instructions).
- When you open this file, your GCP file should automatically be reloaded, however in some cases it is not.
 - ❖ If this is the case, and your GCP file is not reloaded automatically, click on the *Load GCP Points* icon.



- ❖ Navigate to your GCP points file for this map and select it. Your points, map and partially georeferenced map should now be open
- You can continue your georeferencing work now.

Georeferencing using GCPs from features

We will now georeference the map based on features found on both the historic map and the satellite image shown on the Map Canvas.

Adding an initial 6 GCPs from features

- Navigate to the Georeferencer panel.
- Select *Settings > Transformation Settings* and enter the following settings (the only difference from the previous method is that the *Transformation type* will now be set to *Polynomial 2*):

The screenshot shows the 'Transformation Parameters' and 'Output Settings' panels of the Georeferencer tool. The 'Transformation Parameters' panel includes a dropdown for 'Transformation type' set to 'Polynomial 2', a dropdown for 'Resampling method' set to 'Nearest neighbour', and a dropdown for 'Target SRS' set to 'EPSG:4326 - WGS 84'. The 'Output Settings' panel includes a text field for 'Output raster', a dropdown for 'Compression' set to 'None', and a checked checkbox for 'Save GCP points'.

- Input a location and name for the output georeferenced raster in the *Output raster* field. Save the file as '53_C_3_1915_GCPs.tif'. The '_GCPs' at the end of the file name indicates that the georeferenced map has been created using identified feature GCPs.
- Click OK.

The GCP table will still have the 4 corner GCPs in it.

- Untick the box next to these 4 GCPs (this is so that they are not used in the next steps).

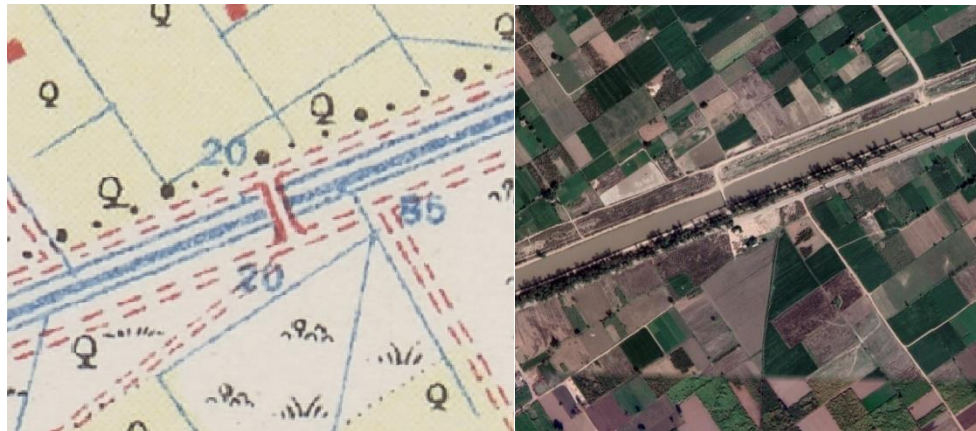
GCP table	
Visible	ID
<input type="checkbox"/>	0
<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3

We now need to start creating our new GCPs based on features visible on the map.

- In the Map Canvas, use the slightly transparent map that you georeferenced in the previous steps (using the four corners) to identify features on the historic map that also appear on the satellite image basemap.
- Ideally, these should be features that have not changed over time, which could include (but are not limited to):
 - Intersections or curves of canals and railroad tracks - these are especially good features that are unlikely to have changed from the time the Survey of India Maps were created. For example, the images below show a GCP that has been selected where a main road crosses a railway:



- Bridges over canals - these are similarly accurate and useful features that have often remained unchanged.

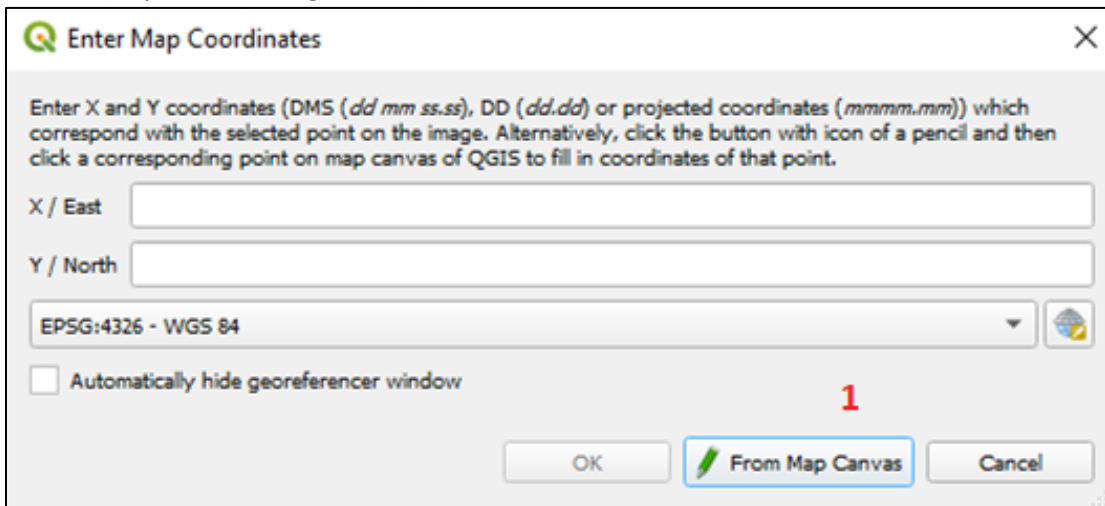


- Roads and field boundaries - these can also be used but are generally less accurate as these are more easily changed over time.
- Many villages will have a main road or intersection near the centre. These can often be used as they are also less likely to change.
- In some areas, temples and places of worship have not changed location since the nineteenth century and can be useful in orienting/positioning GCPs in areas where modern main roads are lacking, however these are not always ideal.

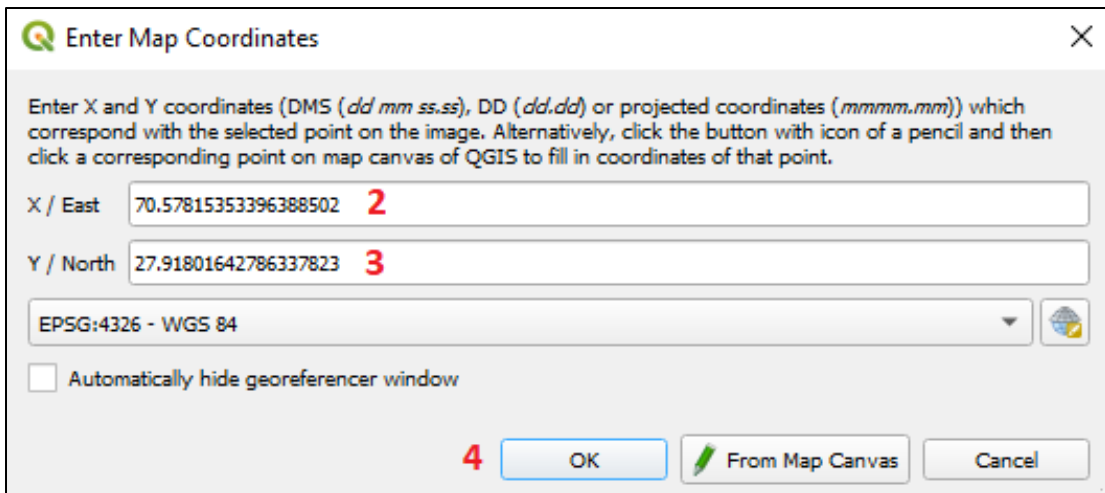
- In order to identify these features, it can be useful to turn the transparent georeferenced map on and off several times just to check that the features are indeed the same. To do this, untick the box next to the layer to turn it off, and tick it to turn it on. Alternatively, you can use the MapSwipe Tool plugin to swipe the georeferenced map on and off.

When you have found a location that you would like to use as a GCP, we need to make a GCP pair between the historic map and the satellite image.

- In the Georeferencer Panel, find the location on the historic map that you would like to make a GCP and left click on it.
- The *Enter Map Coordinates* window will appear. Click on the *From Map Canvas* button (step 1 in the image below).



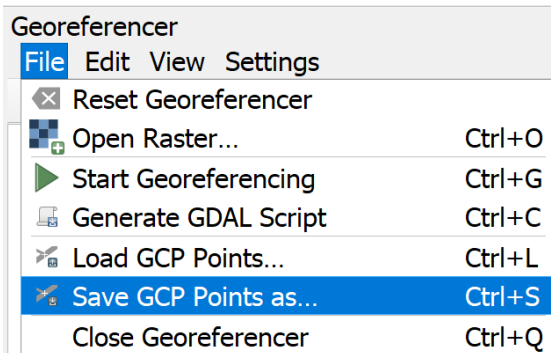
- Your cursor will turn into a cross, and you should use it to select the corresponding location of the GCP on the satellite image basemap in the Map Canvas. Do this by left clicking on the correct location.
- The coordinates of this location will automatically be entered in the X and Y boxes in the *Enter Map Coordinates* window (step 2 and 3 in the below image).



- Click OK (step 4).

The GCP pair will be added to the GCP table in the Georeferencer Panel, and a yellow box with the GCP ID number in it will appear next to the red GCPs points in the Georeferencer Panel and the Map Canvas.

- Initially select 6 GCP points from different locations on the historic map. Try to keep these spread throughout the map.
- Save these 6 points in a GCP file (so that you don't lose them if QGIS crashes!). Click on *File > Save GCP Points as...* in the Georeferencer panel



- Save your GCP points using the name '53_C_3_1915 _points_progress'.

Once you have selected 6 GCP points, you will notice that a value appears for each point in the *Residual (Pixels)* column in the GCP table. Essentially, this number identifies how close the GCP point from your historic map will be to the location you selected for it to be on the satellite image if you were to run the georeferencing process now. The lower the number, the closer the GCP pair will be.


There is also an indication of the accuracy of the GCP points as a whole shown in the bottom right corner of the Georeferencer Panel.

The more GCPs you add, the more likely it is that the *Residual (Pixels)* value will increase, as the polynomial 2 transformation will limit the amount of movement during the georeferencing process. To make sure that the image will be well georeferenced throughout the map, we need to add more GCPs.

Syncing georeferencer with map window

Once you have added the minimum number of GCPs needed for your transformation - in this case 6 are needed for a polynomial 2 transformation - then you are able to link the georeferencer window and the

main QGIS window. This means that as you move around the map searching for more GCPs the georeferencer window will mimic the movement. To do this:

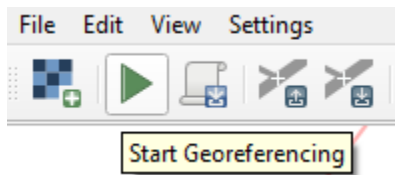
- In the georeferencer window you should see that the following two icons are now coloured (previously they were grey): 
- If you cannot see these, go into *Transformation Settings* and make sure that your *Transformation type* is set to *Polynomial 2*.
- Click on both of the icons. This will link the georeferencer window to the map window and vice versa.
- Try zooming in and out of the map in the map window, you will now see that the georeferencer window copies your movements.

Improving georeferencing accuracy by adding more GCPs

Now we will add a further 14 GCP points so that we have a total of 20, which should improve the overall accuracy of the georeferenced map. Try to keep these spread evenly throughout the map, rather than all in one part of the map, and remember to occasionally save the GCP points file (you can resave over the GCP points progress file you made in the previous step).

After all 20 GCP have been selected, look at the *Residuals (Pixels)* column of the *GCP Table*. The values in this column should be below 30.

- If any GCPs are higher than 30, you may not want to use these for the georeferencing process (as they may incorrectly skew all of the other GCP points). To not use the point, untick the tickbox of that GCP.
- Once you are happy with your GCPs, first save them, and then click the green arrow or go to *File -> Start Georeferencing* in the menu bar of your Georeferencer window.



As with before, a new *tif* file and *.Points* file will be saved in your output folder, and the new georeferenced map layer will be added to the Layers Panel.

- Change the transparency of this new layer or use the MapSwipe Tool to compare it with the basemap. The map should be more accurate than when you georeferenced it just using the corner points.
- If you are not happy with the accuracy, you can add more GCPs and then re-run the georeferencer.
- If you are happy with the accuracy, then congratulations you have completed georeferencing a historic map!
- Remember to save your project before exiting QGIS.

ACTIVITY: Continue your practice at the end of step 4 and georeference your map based on features found on both the historic map and the satellite image shown in the Map Canvas. Add a total of 20 GCPs.